Impact factors on cervical dilation rates in the first stage of labor

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Abstract

Aims: To assess cervical dilation rates of nulliparous and multiparous women in the active first stage of labor and to evaluate significant impact factors.
Methods: In a retrospective cohort study between January 2007 and July 2014 at the University Hospital of Zurich in Switzerland, we analyzed 8378 women with singleton pregnancies in vertex presentation with a vaginal delivery at 34+0 to 42+5 gestational weeks. Median cervical dilation rates were calculated and different impact factors evaluated.
Results: Cervical dilation rates increase during labor progress with faster rates in multiparous compared with nulliparous women ($P < 0.001$). Dilation rates exceed 1 cm/h at a dilatation of 6–7 cm, but are very individual. Accelerating impact factors are multiparity, a greater amount of cervical dilation and fetal occipitoanterior position, whereas the use of epidural anesthesia, a higher fetal weight and head circumference decelerate dilation ($P < 0.001$).
Conclusion: Cervical dilation is a hyperbolic increasing process, with faster dilation rates in multiparous compared to nulliparous women and a reversal point of labor around 6–7 cm, respectively. Besides, cervical dilation is highly individual and affected by several impact factors. The diagnosis of labor arrest or prolonged labor should therefore be based on such rates and on the individual evaluation of every woman.

Keywords: Cervical dilation; dilation rates; first stage of labor; impact factors; labor curve; labor progress; partogram.

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Introduction

In recent years, one focus in obstetrical research was the physiological progress of labor and the discrimination between physiological and nonphysiological labor, especially in order to reduce cesareans and optimize labor management [1]. For the assessment of labor progress, the partogram is a well-established tool. Several studies support that the use of a partogram is associated with improved quality of care and pregnancy outcome [2–4]. The widespread used partogram of the World Health Organization (WHO), based on Friedman's work in the 1950s, has been modified in recent years, and more recent labor curves have been assessed [5–10]. Yet, the problem is that in some studies, as in the largest of Zhang et al., the data of many different centers were evaluated retrospectively, which causes a bias because of the lack of standardized obstetrical care in all the different institutions taking part. However, it is essential that progress of labor is evaluated correctly and truly nonpyhsiological labor identified, as nonphysiological labor is associated with adverse fetal and maternal outcome and a greater proportion of obstetrical interventions, such as oxytocin application and operative vaginal or cesarean delivery [1, 11–15]. The evaluation of labor progress should be best done for different study populations in different geographical areas separately. Labor progress is often assessed by the total duration of labor, in less proportion by the rate of cervical dilation, which better reflects the real progress of labor. In a consensus paper, the National Institute of Child Health and Human Development, the American Congress of Obstetricians and Gynecologists (ACOG) and the Society of Maternal-Fetal Medicine (SMFM) therefore state that the management of the first stage of labor should be based on not only the total duration of labor but also its progress, certainly within set time limits [1, 16, 17]. Besides, the influence of different impact factors on the progress of the first stage of labor has been published in the literature, but mostly with the focus on a single factor. For instance, these factors are maternal body mass index (BMI), age, height and race, constitutional factors, parity, gestational age, fetal head position, fetal weight, labor augmentation or induction of labor, the use of epidural anesthesia and a longer first stage of labor [9, 10, 15, 18–24].

Cervical dilation and fetal descent are the two most important parameters to evaluate labor progress and to be able to discriminate between a normal and an abnormal situation. In the active first stage of labor however, cervical dilation is the main process [1, 7, 13, 25]. The aim of our study was to calculate cervical dilation rates for nulliparous and multiparous women delivering vaginally in a large patient sample with standardized obstetrical care. Besides, we aimed to evaluate several significant impact factors on these rates in the same study group simultaneously.

Methods

Between January 2007 and July 2014, we conducted a retrospective cohort study at the University Hospital of Zurich in Switzerland and evaluated all vaginal births with singleton pregnancies in vertex presentation at a gestational age of at least 34 + 0 gestational weeks (gw). We decided to include pregnancies from 34 + 0 gw on, as care for late preterms (from 34 + 0 to 36 + 6 gw) is recommended the same during labor as care for term births (from at least 37 + 0 gw) [26], according to the guidelines of the German Society of Obstetrics and Gynecology. We excluded multiple pregnancies, noncephalic presentations, placenta previa, fetal malformations and intrauterine fetal demise, critical maternal diseases (such as severe heart and lung diseases, organ transplantations and collagenosis) and cases of incomplete data. The study was approved by the ethical board of the district (KEK-ZH-Nr.2015-0105). Annual delivery rates remained stable in our hospital and ranged between 2600 and 2900 per year in the study period. All deliveries in our hospital were attended by a midwife and an obstetrical resident. Maternal, fetal and obstetrical data were recorded by the attending staff and documented in our computerized data systems (Perinat 5 and Philips IntelliSpace Perinatal information system) during routine prenatal pregnancy care (the baseline characteristics), at admission to our delivery ward (for instance ultrasound evaluation of the fetus), during delivery (for instance the interventions) and postnatally (for instance weight and head circumference of the neonate).

Obstetrical care during labor was standardized in our hospital. The active first stage of labor was defined from 3 to 10 cm of cervical dilatation in the presence of regular uterine contractions, according to the definition of the majority of studies on labor onset and labor progress, for both nulliparous and multiparous women [17, 25]. Vaginal examinations were performed at least every 2 h to monitor labor progress, although this method is known to be somehow inaccurate and there is little consent about the frequency of such examinations. Fetal heart rate and uterine contractions were monitored continuously by cardiotocography in all patients. In terms of inadequate labor progress in the active phase of labor, subject to the ACOG/SMFM consensus recommendations and the ACOG practice guidelines, oxytocin augmentation was applied according to a standardized protocol [1, 17].

Outcomes of the study were the cervical dilation rates in the active phase of labor according to parity and the evaluation of significant impact factors on these rates. As impact factors we evaluated different maternal (BMI, age and parity), fetal (weight, head circumference, head position and gestational age) and obstetrical factors (presence of epidural anesthesia and labor induction). For the purpose of assessing labor progress, the median cervical dilation rates at every centimeter of cervical dilatation and its 10^{th} and 90^{th} percentiles were assessed, according to parity groups.

We chose nonparametric testing with calculation of the median and its 10^{th} and 90^{th} percentiles, as the length of the first stage of labor and the dilation rates were not normal distributed but left skewed. Median fetal descent rates to traverse from one station to another were calculated by interval-censored regression. First, we defined parity groups as nulliparous, primiparous and multiparous (parous 2+) women. Then, the Kruskal-Wallis test was used to determine significant differences in cervical dilation rates at every centimeter of cervical dilation, stratified by these three parity groups. As there were no significant differences between primiparous and multiparous women, these two groups were handled as one group (subsumed as "multiparous") in further statistical analysis. The Mann-Whitney *U*-test was used to evaluate significant differences in dilation rates among the nulliparous and multiparous group. From the median cervical dilation rates, we also calculated the median duration of the first stage of labor for both groups.

Linear mixed models were used to evaluate the significant impact factors. Statistical analysis of the cervical dilation rates was performed using the statistical software package SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). Because of the great sample size, statistical significance was set at $P < 0.001$ for the dilation rates and for the impact factors. Baseline characteristics of nulliparous and multiparous women were compared using the χ^2-test for categorical data and the unpaired *t*-test for continuous data (SigmaPlot 12.0, Systat Software Inc., CA, USA).

Results

In total, 8378 patients were included in the final analysis. Of these 8378 patients, 4269 were nulliparous (51%) and 4109 were multiparous (49%). The characteristics of the study population differed significantly in some factors (Table 1). Nulliparous women were younger, had a smaller BMI, used epidural anesthesia more often, had a lower mean gestational age at birth and had neonates of lower birth weight and smaller head circumference.

Median duration of the active first stage of labor, calculated from 3 cm of cervical dilatation onwards, was 9.47 h in nulliparous and 7.33 h in multiparous women, respectively. From 4 cm of cervical dilatation onwards, the first stage of labor lasted 6.02 and 4.21 h, respectively.

Median cervical dilation rates followed a hyperbolic curve in both groups. The rates increased during the course of labor and ranged from 0.29 to 1.57 cm/h in nulliparous and from 0.32 to 4.47 cm/h in multiparous women. They were significantly faster in multiparous compared with nulliparous women (Figure 1). Significant differences in dilation rates between the groups started with 6 cm of cervical dilatation. Dilation rates of more

Table 1: Characteristics of the study population.

	Nulliparous		Multiparous		P-value
	n=4269	(50.95)	n=4109	(49.05)	
Age (SD), years	29.7	(5.3)	32.2	(5.09)	<0.001
BMI (SD), kg/m²	27.3	(4.1)	28.3	(4.3)	<0.001
Ethnicity caucasian, n (%)	2766	(64.79)	2608	(63.47)	0.207
Epidural anesthesia, n (%)	1323	(30.99)	818	(19.91)	<0.001
Blood loss (SD), mL	442.81	(341.47)	409.98	(359.29)	<0.001
Age of gestation at delivery					
Preterm (34 0/7–36 6/7), n (%)	257	(6.02)	139	(3.38)	<0.001
Term (37 0/7–42 0/7), n (%)	4012	(93.98)	3970	(96.62)	<0.001
Fetal position occipitoanterior, n (%)	4135	(96.86)	3959	(96.35)	0.193
Gender					
Male, n (%)	2144	(50.22)	2016	(49.06)	0.289
Female, n (%)	2125	(49.78)	2093	(50.94)	0.289
Fetal weight (SD), g	3305.52	(457.35)	3472.26	(460.93)	<0.001
Head circumference (SD), cm	34.56	(1.45)	34.76	(1.37)	<0.001
Labor induction, n (%)	1031	(24.15)	963	(23.44)	0.443

Data are presented as mean (SD) or n (%).

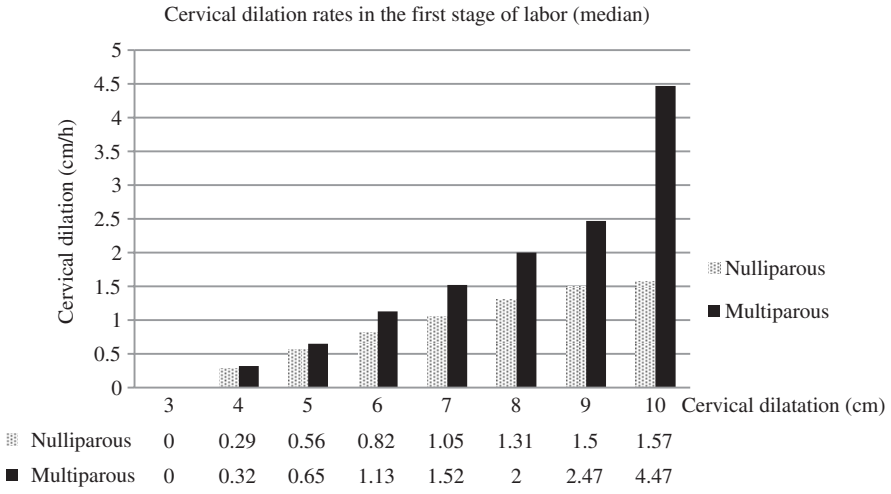

Figure 1: Median cervical dilation rates of nulliparous and multiparous women in centimeter per hour (cm/h) at every centimeter of cervical dilatation.

than 1 cm/h were found with a cervical dilatation of 6 cm or more in multiparous and of 7 cm or more in nulliparous women. The corresponding 10th and 90th percentiles showed a wide range of dilation rates in both groups, but in a much greater amount in the multiparous group (Figure 2). Comparing the WHO partogram with ours and other more recent partograms, it is clear that continuous dilation rates of 1 cm/h are not appropriate and too fast at the beginning and too slow at the end of the first stage of labor for contemporary parturients (Figure 3).

Significant decelerating factors on dilation rates were higher fetal head circumference, fetal weight and the presence of epidural anesthesia. Accelerating factors were fetal occipitoanterior position, a greater amount of cervical dilatation and multiparity (Table 2).

Discussion

Cervical dilation rates in the active phase of labor differ significantly between nulliparous and multiparous women in our study, with faster cervical dilation in multiparous women, especially beyond 6 cm of cervical dilatation. In

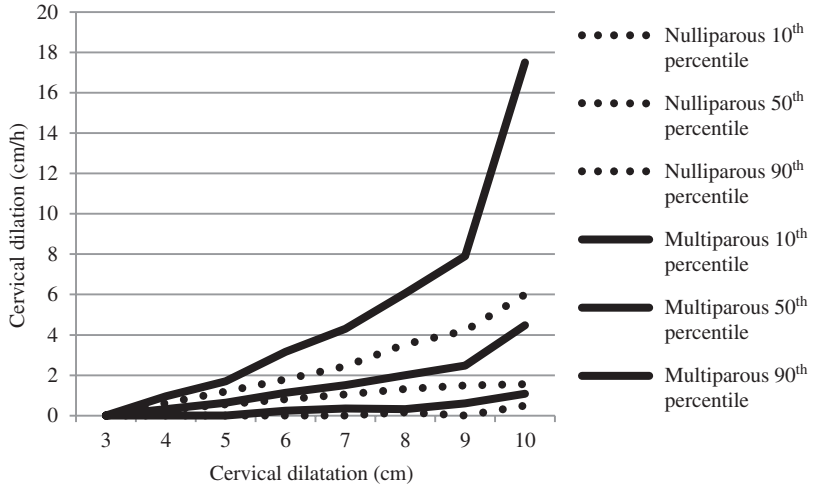

Figure 2: Median, 10th and 90th percentiles of cervical dilation rates according to parity.

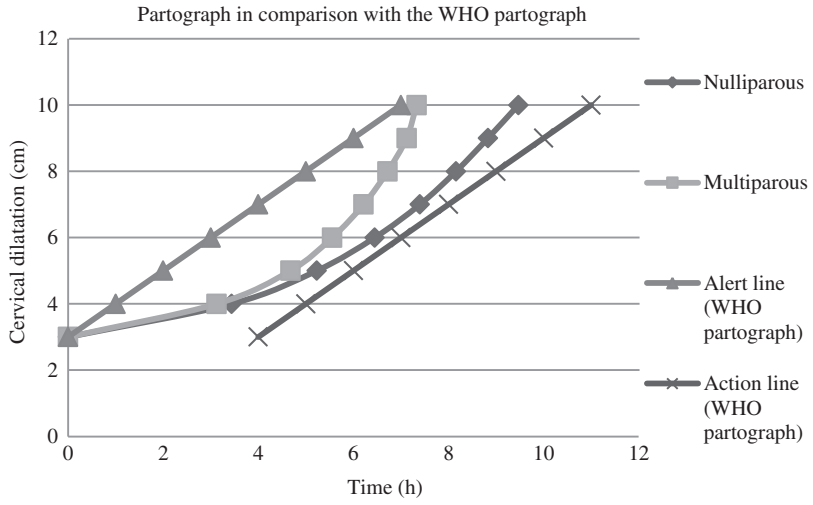

Figure 3: Median cervical dilatation according to parity in comparison with the WHO partograph.

Table 2: Significant impact factors on cervical dilation rates.

Parameter	Impact	P-value	Fixed effects (95% CI)
Higher cervical dilation	↗[a]	< 0.001	+ 0.17 (0.16 to 0.17)
Multiparity (vs. nulliparity)	↗[a]	< 0.001	+ 0.40 (0.38 to 0.43)
Fetal occipitoanterior position (vs. fetal occipitoposterior position)	↗[a]	< 0.001	+ 0.12 (0.06 to 0.19)
Increasing fetal weight	↘[a]	< 0.001	– 0.00 (0.00 to – 8.80)
Increasing fetal head circumference	↘[a]	< 0.001	– 0.03 (– 0.04 to – 0.02)
Use of epidural anesthesia (vs. without epidural anesthesia)	↘[a]	< 0.001	– 0.21 (– 0.24 to – 0.18)
Increasing BMI	↗	0.104	0.00 (0.00 to 0.01)
Labor induction vs. spontaneous onset	↗	0.001	+ 0.05 (0.02 to 0.07)
Gestational age preterm (vs. gestational age term)	↘	0.445	– 0.03 (– 0.09 to 0.04)
Increasing maternal age	↘	0.010	– 0.00 (– 0.00 to – 0.00)

[a]Significant statistical difference ($P < 0.001$).
Impact: ↗ accelerating factor, ↘ decelerating factor, significance level $P < 0.001$.

addition, we found a wide range of dilation rates between patients at every centimeter of cervical dilatation, especially in multiparous women, which signals a highly individual process of delivery. Finally, several significant impact factors on labor progress were evaluated and have to be taken into account when assessing labor progress.

A weakness of the study is that the timing of the epidural application differed between women, and the reason for the epidural application (either just for pain relief or as an intervention due to obstructed labor) was not recorded and could therefore not be considered in the analysis. In our study, the use of epidural anesthesia is associated with slower labor progress. Therefore, the timing of epidural anesthesia is associated with altered median cervical dilation rates at a given dilatation. Moreover, the timing and amount of oxytocin use was not evaluated in this study, as it was not in other studies [27, 28].

The problem hereby is to get correct partograms of physiological vaginal deliveries as an evaluation of many deliveries without any kind of obstetrical intervention would be needed for this purpose. However, in contemporary obstetrical care, such an ideal situation is an illusion.

In fact, modern partograms are generated from large data sets of a modern obstetrical patient sample, but obstetrical care differs widely between countries and hospitals. Therefore, a comparison is not always easy and representative.

A strength of our study is the large sample size of more than 8300 deliveries in a single tertiary care center with a standardized protocol of obstetrical care and documentation. For example, in contrast to the study of Graseck, the frequency of vaginal examinations was standardized in our hospital [8]. Another strength is the examination of several different impact factors in the same large sample size, as other studies dealt only with single or few impact factors.

Cervical dilation rates

Since Friedman's work on partograms, many efforts have been made to develop sufficient tools for labor assessment in order to distinct between physiological and abnormal labor progress and to correctly initiate obstetrical interventions for the purpose of a better outcome for mother and child [5, 6, 29–31].

Based on Friedman's work, in the 1990s, the WHO defined the beginning of the active first stage of labor at 3–4 cm of cervical dilatation and assumed a continuous dilation rate of 1 cm/h as physiological. No differences between parity groups were made at that time. In that partogram, an alert line was integrated, representing the slowest 10% of parturients [3]. Four hours right to the alert line, the action line was added to indicate the necessity of interventions when crossing that line.

A well-known problem in obstetrical care is the lack of uniform definitions of the labor stages, especially for the first or active first stage of labor [25]. Depending on the definition when labor begins, it results in different durations of labor and dilation rates.

According to the definitions of Neal et al. [32] supported by the guidelines and recommendations of ACOG and SMFM and the work of Zhang et al. [7], the active phase of the first stage of labor begins at around 6 cm of cervical dilatation. In our work, we found a cervical dilation rate faster than 1 cm/h at the dilatation of 6 cm in multiparous women, but in nulliparous women not even until 7 cm of dilatation. According to Neal et al. [14], the latent phase of the first stage of labor should not exceed 18 h, regardless of parity. Because of a slower progress at the beginning of the first stage, but incongruent assessments of the latent phase, we cannot define a given time frame or time limit for the labor duration before 6 cm of cervical dilatation. However, we agree that the diagnosis of labor arrest should be stated with caution and obstetrical interventions should be applied with restraint before 6 cm of dilatation [1, 14]. For the diagnosis of labor protraction, Neal et al. [14] recommend the application of adapted partograms to at least parity and even better to more other impact factors. They assessed a protracted course of labor at a dilation rate of less than 0.5–0.7 or 0.5–1.3 cm/h, representing the 90th and 95th percentiles in nulliparous and multiparous women [14]. With our work, we assessed such basic partograms for different parity groups, and with the evaluation of different impact factors on these partograms, we helped to lay another foundation for a proper interpretation of labor courses.

Most published studies evaluated the total duration of the first stage of labor, especially the mean duration, to distinguish between normal and abnormal labor, but lacked to evaluate the progress of cervical dilation in that stage [28, 32]. The total duration of the first stage of labor alone is an insufficient marker to distinguish physiological from nonphysiological labor [1, 32].

As we and others could show, the duration of labor is left skewed, so in first line, the median and not the mean values should be assessed, as we did here [10, 28, 33]. Compared to the systematic review of Neal et al. [28] in 2009, where a median first stage of labor for nulliparous women of 5.4 h (single studies ranging from 2.75 to 7.32 h) is assessed, our median duration is 6.02 h in this group. Other studies assessed the mean duration of the first

stage of 4.9 to 10.2 h in nulliparous women [30, 34, 35]. For multiparous women, we found a median duration of the first stage of 4.21 h, whereas Zhang et al. [7] found 2.4 h. The mean values in other studies range from 5.6 to 7.4 h [30, 34].

As cervical dilation follows a hyperbolic curve, the total duration of the first stage inadequately describes the situation and dilation rates in the course of delivery should be preferred to the total duration.

Hence, with our work we assessed cervical dilation rates. We found rates from 0.29 to 1.57 cm/h in nulliparous and from 0.32 to 4.47 cm/h in multiparous women. Zhang et al. had slightly faster values of 0.8–2.5 and 1.4–5 cm/h, respectively.

In addition, we could show that cervical dilation is an individual process with great interindividual differences in dilation rates, especially for multiparous women and at the end of the first stage of labor (Figure 2). Besides these interindividual differences in labor progress, we could show in agreement with others that several maternal, fetal and obstetrical parameters have an influence on labor progress.

Impact factors

We found that multiparity, a greater amount of cervical dilation and fetal occipitoanterior position are significantly accelerating impact factors on cervical dilation rates ($P < 0.001$), which is according to the findings of others [24, 30].

In our study, significantly decelerating impact factors on cervical dilation rates were the use of epidural anesthesia, a higher fetal weight and head circumference, which is according to other findings [19, 36].

Regarding the use of epidural anesthesia, it might be important at which cervical dilatation it was applied. The application of epidural anesthesia in the early first stage of labor seems not to prolong labor progress, whereas application in the late first stage seems to be associated with a slower labor progress [22, 37]. However, the association of epidural application in the late first stage might be due to prolonged labor, often caused by fetal occipitoposterior position or macrosomia. Thus, the often proposed delay of labor progress in cases of epidural application might therefore partly be due to the reason why the epidural was applied, not due to the epidural itself.

Other factors, not significantly influencing cervical dilation rates, are increasing maternal BMI, labor induction, maternal age and preterm gestational age, which is partly according, partly in contrast to other authors [9, 18, 20, 23]. The first two factors have the tendency to accelerate labor progress, whereas the last two ones to decelerate progress in our study.

There is no significant impact of increasing BMI in our study. By contrast, Vahratian et al. [23] and Kominiarek et al. [38] found longer durations of the first stage of labor and slower cervical dilation rates in overweight or obese women, but mostly before a dilatation of 4–7 cm. However, in both studies, median traverse times per centimeter of cervical dilation mainly do not differ between maternal weight groups after a dilatation of 4–6 cm, which strengthens our results [23, 38]. Only the traverse times at the beginning of the first stage of labor are slower with increasing maternal weight [38]. Our group of nulliparous women had a mean BMI of 27.3 kg/m^2, and the group of multiparous women had a mean BMI of 28.3 kg/m^2. Compared to the weight group "25–29 kg/m^2" of Kominiarek et al. [38] and the weight group "26–29 kg/m^2" of Vahratian et al. [23], we found almost the same cervical dilation rates.

Induction of labor had the tendency to accelerate labor in our study, but the P-value of 0.001 was not significant, which is according to the findings of Cheng et al. [15] and Vahratian et al. [39]. There are controversies about the influence of labor induction on the progress of labor, especially on the first stage of labor [40, 41]. For instance, Rinehardt et al. [40] and Ostborg et al. [42] state a longer active phase of labor for induced women, whereas Friedman [41] doubts these results and Hoffman et al. [43] even found the contrary. However, the results of Vahratian et al. [39] were limited to multiparous women only. Induction is used before or during the latent phase and may produce painful contractions with a certain amount of change in cervical dilatation early in the induction process. Thus, induced women might be earlier declared as "in labor" as women without induction, especially when "painful contractions" or "changes in cervical effacement" are used for the definition of labor onset [25]. The problem of defining labor onset and therefore the assessment of the transition from latent to active phase of the first stage of labor remains difficult [25]. Thus, labor induction might either influence only the latent phase or the active phase or both, depending on the definitions applied.

Increasing maternal age as an impact factor could not reach a statistical significant level in our study. In a study of Zaki et al. [20], maternal age had an accelerating effect on labor progress with increasing maternal age, divided into four groups from < 20 years to > 40 years of age. In our study, we calculated constantly increasing maternal age as an impact factor and did not set up predefined age groups.

Preterm gestational age had the tendency to decelerate cervical dilation rates in our study but was not statistical significant. These findings are strengthened by a study of Feghali et al. [44], where increasing gestational age in induced preterm nulliparous women was associated with a shorter duration of labor between different preterm groups, but also compared with term deliveries.

We state that delivery is a highly individual process with great interindividual differences, but with some general tendencies. As the process of labor is so individual, it is difficult to set up precise time limits or dilation rates for the initiation of obstetrical interventions or for the definition of labor arrest. Many efforts have been made to set up such time limits or criteria for progression failure, some of them including single impact factors [1, 16].

We could show that labor progress is significantly accelerated and decelerated by different impact factors, especially after a cervical dilatation of 6 cm. So it is important to not only focus on the total duration of labor or on median or mean cervical dilation rates alone, but also include possible impact factors in the analysis of every single woman's labor progress. By this, unnecessary interventions might be avoided or necessary interventions initiated.

Conclusion

Cervical dilation exponentially increases during labor. Therefore, modern partograms differ substantially from the linear-shaped WHO partogram. Dilation rates differ between parity groups, with faster dilation rates in multiparous compared with nulliparous women. The reversal point of labor, where dilation rates exceed 1 cm/h, and therefore the beginning of the active first stage of labor lays around 6–7 cm of cervical dilatation, respectively. The time before is mostly part of the latent phase with a more or less continuous transition into the active phase. Besides, cervical dilation is a highly individual process and is affected by several impact factors. Accelerating impact factors are multiparity, induction of labor, a greater amount of cervical dilation and fetal occipitoanterior position, whereas the use of epidural anesthesia, a higher fetal weight and head circumference decelerate dilation. In order to minimize unnecessary interventions and improve maternal and fetal outcomes, the diagnosis of labor arrest or prolonged labor should therefore be based on such rates and impact factors as well as on the individual evaluation of every woman. In the future, an evaluation of the timing of and the underlying reason for epidural anesthesia and oxytocin application would be favorable.

Author's statement

Conflict of interests: The authors of this manuscript have no conflicts of interest to disclose as described by the Journal of Perinatal Medicine.

Material and methods: Informed consent: Informed consent has been obtained from all individuals included in this study.

Contribution to authorship: JJ: Data management, statistical analysis, writing of the manuscript. MK: Study design and revision of the manuscript. RZ: Study design and revision of the manuscript. NK: Study design, data management, statistical analysis and writing of the manuscript.

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